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A taxonomic review of *Delias aroae* species complex *s. str.* (Lepidoptera, Pieridae) belonging to New Guinea

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Abstract The *Delias aroae* species complex *s. str.* (Lepidoptera, Pieridae) has been taxonomically reviewed. The morphology of male adults within the species complex based on five characteristics: vein CuA1 length, black width index, wing marking underside, scent scale length of the forewing and genitalia are examined and described. The extent of the black apical band on the upperside of the forewing was observed as an east–west cline in *D. aroae* and *D. pheres*, which are widely distributed species on the island of New Guinea. On the basis of the results, *D. aroae yabensis* and *D. pheres approximata* have been revived. , and *D. balimensis* (originally *D. aroae balimensis*) is newly synonymized with *D. a. aroae*.

Key words Pieridae, *Delias aroae* species complex, New Guinea, morphology, east–west cline.

Introduction

The *aroae* species complex *s. str.* is a group of species with similar wing shape and patterns, which belongs to the genus *Delias* of the family Pieridae.

Talbot (1928) studied the morphology of the species complex, which he classified into *D. aroae* (Ribbe), 1900 and *D. pheres* Jordan, 1911 mainly based on three characteristics: male genitalia, female genitalia and scent scale. In his monograph, Talbot divided *D. aroae* in Papua New Guinea into two geographical races: *D. aroae yabensis* Joicey & Talbot, 1922 from the Weyland Mountains and *D. aroae angiensis* Talbot, 1928 from the Arfak Mountains. Moreover, *D. pheres* comprises one geographical race, *D. pheres approximata* Joicey & Talbot, 1922 in the Weyland Mountains.

Orr and Sibatani (1985) stated that the species complex consists of seven taxa: *D. aroae*; *D. a. balimensis* Roepke, 1955 (current status: *D. balimensis*); *D. a. yabensis* (current status: *D. yabensis*); *D. a. angiensis* (current status: *D. angiensis*); *D. pheres*; *D. p. approximata* (current status: *D. approximata*) and *D. subapicalis* Orr & Sibatani, 1985, and can be distinguished from three subdivisions of the *D. aroae* group (*hyperapproximata* species complex, *flavissima* Orr & Sibatani, 1985, *kenricki* Talbot, 1937) based on the differences in wing shape and pattern.

Delias inopinata Lachlan, 2000 was described from Papua New Guinea. In the original description, He noted "*D. inopinata* should be placed in the *aroae* species complex as defined by Orr and Sibatani (1985)", and *D. inopinata orri* Mastrigt, 2003 was described as a subspecies from West Papua. Moreover, *D. subapicalis sibatanii* Mastrigt, 2003 was described from West Papua, and is subspecies of *D. subapicalis* in the species complex.

Consequently, ten named taxa are currently recognized in the species complex: *D. aroae*; *D. balimensis*; *D. yabensis*; *D. angiensis*; *D. pheres*; *D. approximata*; D. *subapicalis*; *D. s. sibatanii*; *D. inopinata* and *D. i. orri*.

The members of the species complex are very similar to each other in general appearance. In particular, they are difficult to classify based on the markings on the underside of the hindwings. In addition, wide intraspecific variations are observed in the black apical area on the upperside of the forewings. The extent of the black apical area is the main distinguishing characteristic used to classify the subspecies of *D. aroae* and *D. pheres*. However, these variations have not yet been clearly identified. This is one of the reasons for the taxonomic confusion surrounding this species complex.

In their revision, Orr and Sibatani (1985) noted "Rather we feel that a trinomial system would impose an artificial structure on our classification which would misrepresent our knowledge of the situation." Thus, they suggested that "as we use it, a binomial classification is essentially a system of cataloguing and is non-committal regarding the status of certain forms."

In this review, I re-examined the morphology of male adults in detail and attempted to group the species within the species complex based on recent material.

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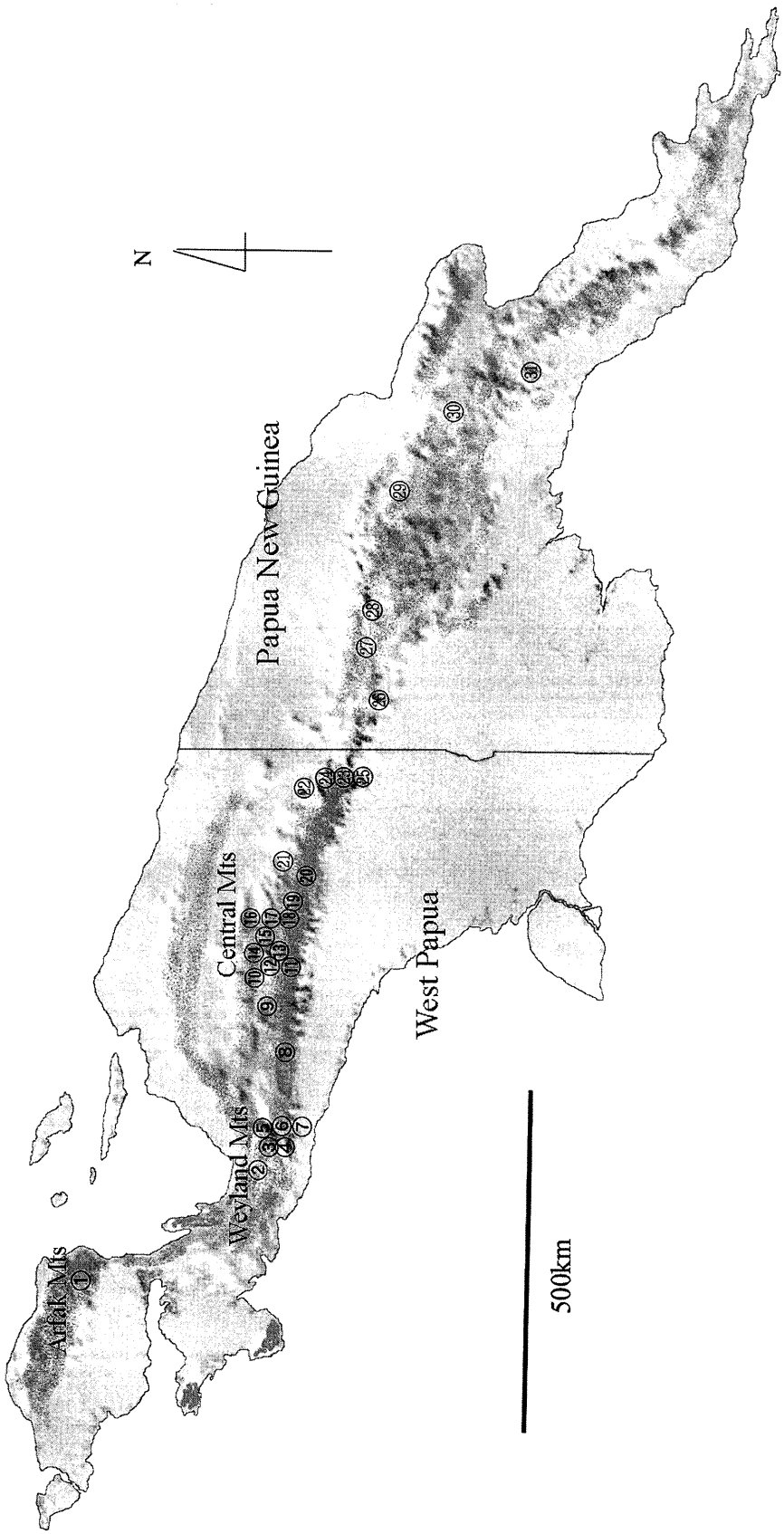

Fig. 1. Study sites. Numerals indicate the localities from where the samples were obtained. 1, Arfak Mountains (Mt Hing), West Papua; 2–7, Weyland Mountains, West Papua (2, Mapia; 3, Bomomani; 4, Idedua; 5, Epomani; 6, Kamu Valley; 7, Moanamani); 8–25, Central Mountains, West Papua (8, Tembagapura; 9, Iraga; 10, Kanggime; 11, Mbua; 12, Tiom; 13, Habbema; 14, Makki, 15, Welesi; 16, Kobakma; 17, Pass Valley; 18, Pugima; 19, Yohosin; 20, Langda; 21, Aipomek; 22, Borme, 23, Abmisibil; 24, Batimban; 25, Okibibab); 26–31, Papua New Guinea (26, Bolobip; 27, Bimin; 28, Bak; 29, Kerowagi; 30, Okapa; 31, Aseki).

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Table 1. Positions of study sites, with numerals as shown in Fig. 1.

Regions	Sites	Longitude	Region	Sites	Longitude	Region	Sites	Longitude	Regions	Sites	Longitude
Arfak Mts	1: Mt Hing	133°50′E		8: Tembagapura	136°50′E		16: Kobakma	139°10′E	Central Mts (W. Papua)	24: Batimban	140°40′E
	2: Mapia	135°50′E		9: Iraga	137°40′E		17: Pass Valley	139°10′E		25: Okibibab	140°40′E
	3: Bomomani	136°00′E		10: Kanggime	138°20′E		18: Pugima	139°10′E	Papua New Guinea	26: Bolobip	141°40′E
Weyland Mts (W. Papua)	4: Idedua	136°00′E	Central Mts (W. Papua)	11: Mbua	138°30′E	Central Mts (W. Papua)	19: Yohosin	139°20′E		27: Bimin	142°10′E
	5: Epomani	136°10′E		12: Tiom	138°30′E		20: Langda	139°40′E		28: Bak	142°20′E
	6: Kamu Valley	136°10′E		13: Habbema	138°40′E		21: Aipomek	139°50′E		29: Kerowagi	144°60′E
	7: Moanamani	136°10′E		14: Makki	138°40′E		22: Borme	140°30′E		30: Okapa	145°30′E
				15: Welesi	138°50′E		23: Abmisibil	140°40′E		31: Aseki	146°10′E

Materials and Methods

In this review, "New Guinea" refers to the whole island, comprising the western half—West Papua (formerly Irian Jaya) and the eastern half—the mainland of Papua New Guinea.

The present study is based on 334 fixed specimens from 31 study sites in New Guinea (Fig. 1 and Table 1), and the following species/subspecies were compared: *D. aroae*; *D. yabensis*; *D. balimensis*; *D. angiensis*; *D. pheres*; *D. approximata*; *D. subapicalis*; *D. s. sibatanii*; and *D. inopinata* except one taxon (*D. inopinata orri*). The specimens are illustrated in Figs 2–17.

The ratio of the black width on the vein and CuA_1 length of the upperside of forewings was calculated to obtain the "black width index (Fig. 18)". The width of the black apical area between the apex and vicinity of the discocellular veins on the upperside of the forewings was not adopted here because of the wide intraspecific variation. In addition, the length of the scent scale on the upperside of the forewing in the male was measured (10 scales per specimen); the measurement was performed from the base of the scale to its tip. Male genitalia was dissected after being macerated for approximately 30 min in 10% KOH heated in a water bath. The KOH-treated material was washed in alcohol, observed under both binocular and optical microscopes, and measured using a micrometer.

For statistical analysis was performed using Excel 2007 (Microsoft, USA) with the add-in software Statcel 3 (Yanai, 2011). The homogeneity of the groups was confirmed by analyzing Bartlett's test. The CuA_1 and scent scale length of the forewings were analyzed by one-way ANOVA, and then differences among the means of the length were analyzed using the Tukey–Kramer multiple comparison test. The black width index of the forewings was analyzed using the Steel–Dwass test. Differences between groups were considered significant at $p < 0.01$.

Description of characteristics

***Delias aroae* (Ribbe)** (Figs 2, 10, 19, 27, 32–37, 56–67, 92–101)

Pieris aroae Ribbe, 1900: 346.

Delias aroae (Ribbe): Rothschild, 1904: 314, pl. 2, fig. 4; Fruhstorfer, 1911: 129; Talbot, 1928–1937: 190, 192, 193, pl. 2, fig. 38 (uncus); Talbot, 1932: 84; Orr & Sibatani, 1985: 7, fig. 1, 17–21; Parsons, 1999: 306, 307, pl. 10 (dorsum & valva), pl. 34, figs 837–840; Yagishita, 1993: 103, pl. 48, figs 1, 2, text 113; Tuzov, 1995: 114; Mastrigt, 2003: 64, 65.

Delias aroa aroa [*sic*] Ribbe: Roepke, 1955: 204; D'Abrera, 1990: 133.

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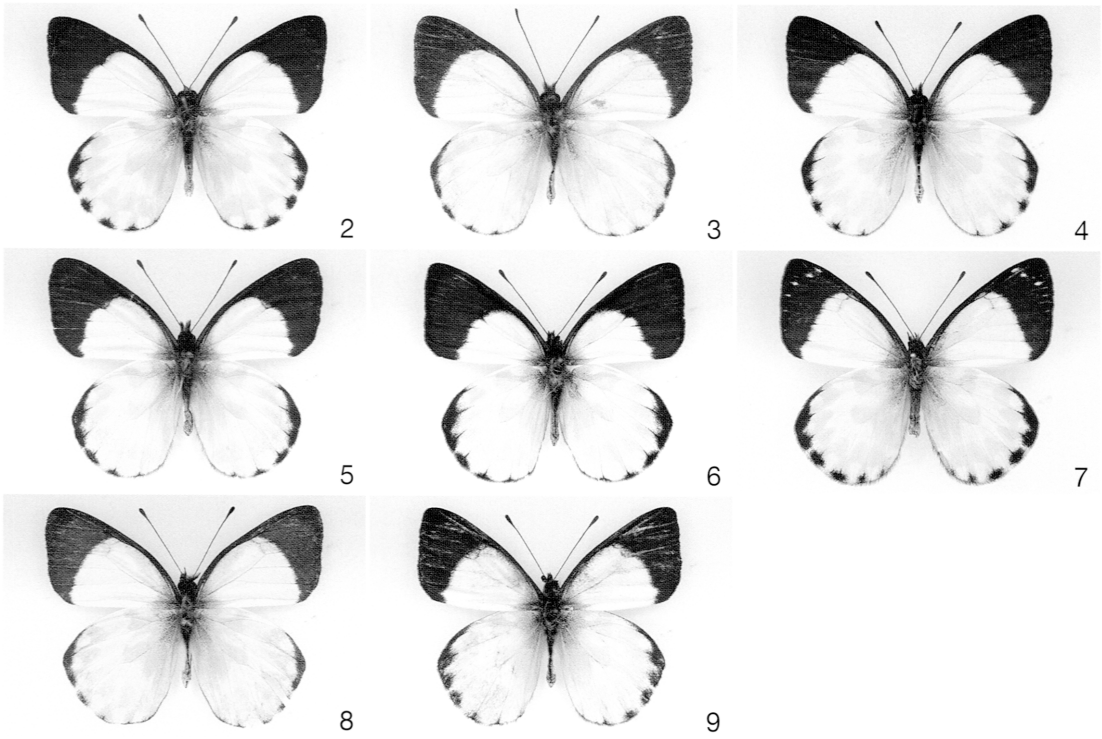
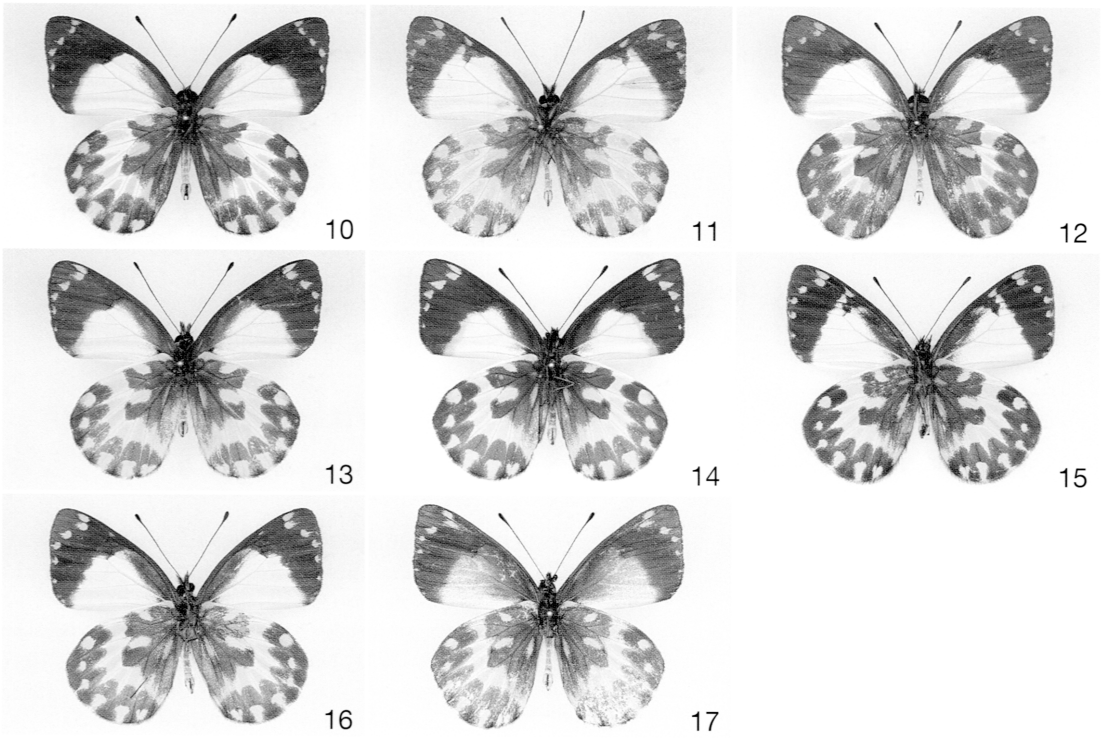


Figs 2–9. *Delias* spp., male, upperside. 2: *D. a. aroae* (Bimin). 3: *D. a. yabensis* (Mapia). 4: *D. angiensis* (Arfak Mountains). 5, 6: *D. p. pheres* (Yohosin). 7: *D. s. subapicalis* (Kerowagi). 8: *D. s. sibatanii* (Pass Valley). 9: *D. i. inopinata* (Bolobip).



Figs 10–17. *Delias* spp., male, underside. 10: *D. a. aroae* (Bimin). 11: *D. a. yabensis* (Mapia). 12: *D. angiensis* (Arfak Mountains). 13, 14: *D. p. pheres* (Yohosin). 15: *D. s. subapicalis* (Kerowagi). 16: *D. s. sibatanii* (Pass Valley). 17: *D. i. inopinata* (Bolobip).

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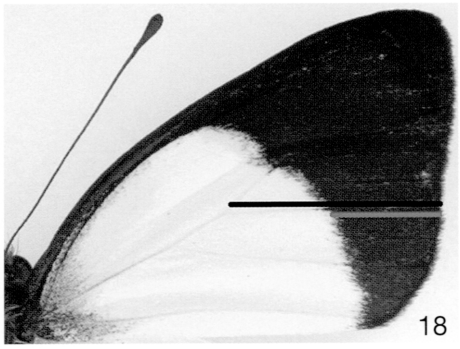


Fig. 18. Black width index (length of black width of vein CuA_1/ vein CuA_1 length). Enlargement of upperside of right forewing of *D. a. aroae* (black line, vein CuA_1 length; red line, length of black part of vein CuA_1).

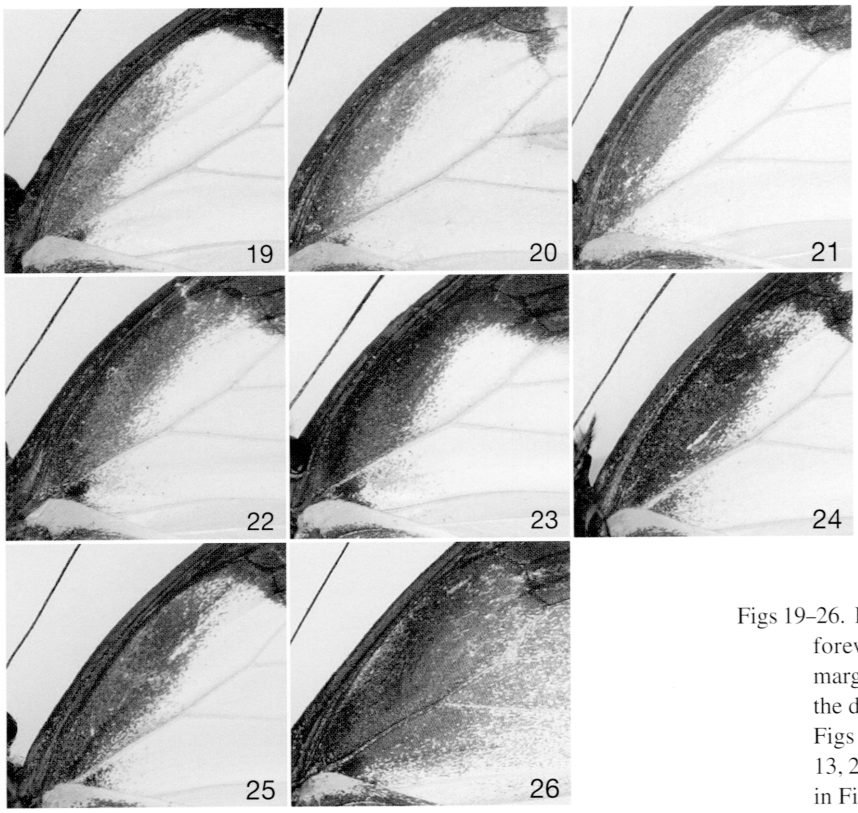
Delias aroa [*sic*] *balimensis* Roepke: 1955: 204, 205; D'Abrera, 1990: 134. **syn. nov.**

Delias balimensis Roepke: Orr & Sibatani, 1985: 11, 13, fig. 16; Yagishita, 1993: 105, pl. 49, figs 1, 2, text 115; Tuzov, 1995: 114; Nishiyama & Arima, 1996: 6, pl. 1, figs 2, 3; Mastrigt, 2003: 65.

Forewing (male). Vein CuA_1 length: [West Papua] 8.8–11.0 mm, 9.92 ± 0.49 mm (mean ± SD, n = 62); [Papua New Guinea] 8.7–10.9 mm, 9.91 ± 0.39 mm (mean ± SD, n = 38). Black width index: [West Papua] 0.36–0.50, 0.43 ± 0.03 (mean ± SD, n = 62); [Papua New Guinea] 0.42–0.56, 0.48 ± 0.03 (mean ± SD, n = 38). Wing marking underside (Fig. 19): extent of black marginal band less than 1/2 of discal cell area. Scent scale length: 283–360 μm, 329 ± 0.03 μm (mean ± SD, n = 80).

Male genitalia (Fig. 27): Phallus (Figs 32–37): cephalic portion of the basal prong in lateral view is considerably reduced compared with caudal portion of basal prong; Juxta (Figs 56–67): arrowhead shaped, 0.36–0.50, 0.44 ± 0.04 (mean ± SD, n = 12) times as long as its median width; Uncus (Figs 92–101): outer lobes in dorsal view relatively shorter than the middle lobe.

Material examined (n = 100♂): [West Papua] 3♂, 22–24. vi. 1995. Kangime, Nallgi River; 4♂, 20–21. vi. 1995. *ditto*, Usak River; 6♂, 18–20. xi. 1993. Pass Valley, Bion River; 4♂, 18–24. xii. 1995. *ditto*, Ameagi River; 16♂, 6. xii. 1994. Kobakma (*ca.* 800 m), Jasmin leg.; 3♂, 27, 28. iv. 1991. Welesi (*ca.* 2,000 m), S. Morinaka leg.; 7♂, 12. ix. 1995. *ditto*, K. Funahashi leg.; 2♂, 16. iii. 1998. Mbua, Ponpan River, W. Ones leg.; 1♂, 6–13. v. 1995. Habbema; 3♂, 4. ix. 1999. Pugima, Huan River (*ca.* 2,420 m), K. Funahashi leg.; 1♂, 2. ix. 1993. Pass Valley–Kobakma, K. Funahashi leg.; 2♂, 8. ix. 1996. Borme, Borme River (*ca.* 1,240 m), K. Funahashi leg.; 14♂, vii.



Figs 19–26. Enlargement of underside of left forewing showing extent of black marginal band along costal vein in the discal cell (19; in Figs 10, 20; in Figs 11, 21; in Figs 12, 22; in Figs 13, 23; in Figs 14, 24; in Figs 15, 25; in Figs 16, 26; in Fig. 17).

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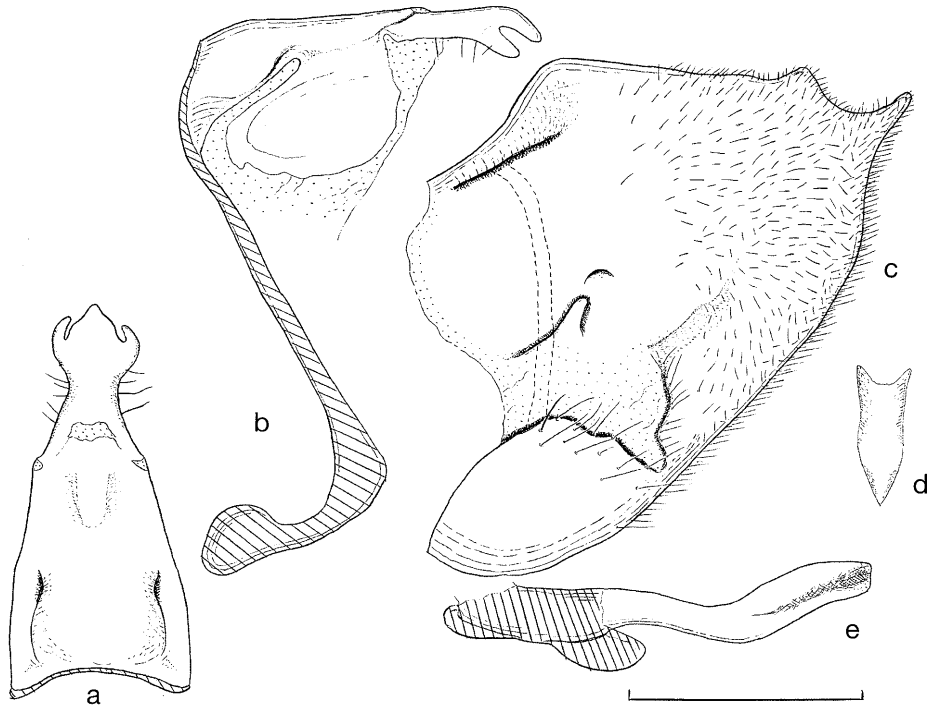

Fig. 27. Male genitalia of *Delias a. aroae* from Okapa, Papua New Guinea. a: dorsum (dorsal). b: ring (lateral). c: valva (inner aspect, right side). d: juxta (posterior); e, phallus (lateral). Scale bar 1 mm.

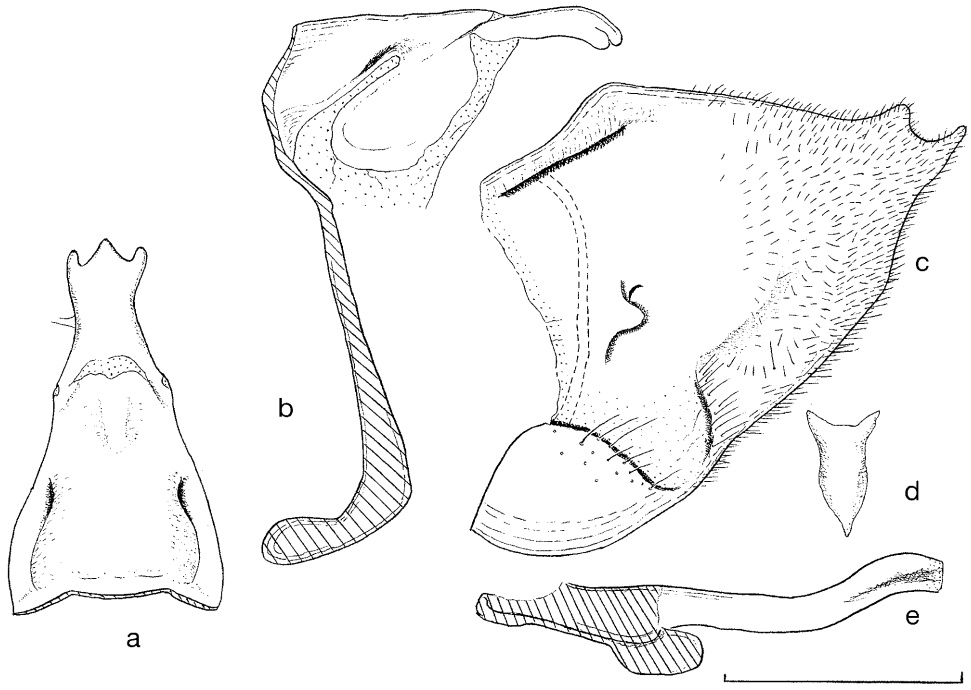

Fig. 28. Male genitalia of *Delias angiensis* from Arfak Mountains, W. Papua. For explanation of a–e, see legend of Fig. 27. Scale bar 1 mm.

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1995. *ditto*, Ailme River. [Papua New Guinea]: 20♂, 11. viii. 2000. Bimin (West Sepik Prov.), Woba River (*ca.* 1,900 m), K. Funahashi leg.; 3♂, ix. 30. 2001. Bak (West Sepik Prov.), Wadin River, M. Patrick leg.; 5♂, 16. Vii. 1995. Okapa (Eastern Highland Prov.); 6♂, 2. ii. 2000. *ditto*; 1♂, i. 1995. Sambio, Mueng (Morobe Prov.).

***Delias aroae yabensis* Joicey & Talbot, stat. rev.** (Figs 3, 11, 20, 38–40, 68–79, 102–106)

Delias aroae yabensis Joicey & Talbot, 1922: 308, 309, pl. 8 (1924), figs 8–10; Talbot, 1928–1937: 191, 192, pl. 6, fig. 20 (signum), pl. 22, fig. 39 (scent scale); 1932: 84.

Delias aroa [*sic*] *yabensis* Joicey & Talbot: Roepke, 1955: 204; D' Abrera, 1990: 134; Schmitt, 1992: pl. 10, figs 5, 10.

Delias yabensis Joicey & Talbot: Orr & Sibatani, 1985: 13, 14, fig. 2, 29–31; Yagishita, 1993: 105, pl. 49, figs 3–8, text 116; Tuzov, 1995: 114; Mastrigt, 2003: 68, 69, pl. 4, figs 1–4.

Forewing (*male*). Vein CuA_1 length: 9.4–10.9 mm, 10.15 ± 0.38 mm (mean ± SD, n = 26). Black width index: 0.31–0.45, 0.37 ± 0.03 (mean ± SD, n = 26). Wing marking underside (Fig. 20): extent of black marginal band less than 1/2 of the discal cell area. Scent scale length: 288–340 μm, 310 ± 14.05 μm (mean ± SD, n = 20).

Male genitalia: Phallus (Figs 38–40): cephalic portion of basal prong in lateral view relatively reduced compared with caudal portion of basal prong; Juxta (Figs 68–79): arrowhead shaped, 0.39–0.55, 0.50 ± 0.05 (mean ± SD, n = 12) times as long as its greatest width; Uncus (Figs 102–106): outer lobes well developed, equal in length to the middle lobe.

Material examined (n = 26♂): 2♂, 23. xii. 1990. Kamu, Ekemanida Tuka River; 7♂, ii. 1990. Epomani; 5♂, vii. 1992. Mapia; 2♂, v. 1992. Idedua (*ca.* 1,700 m); 1♂, viii. 25. 1991. Mapia, Uglda River; 4♂, ix. 19. 1990. Mapia, Gopouya River; 1♂, vii. 1996. Moanamani; 4♂, viii. 31. 1991. Bomomani, Epokunu River.

***Delias angiensis* Talbot** (Figs 4, 12, 21, 28, 41–43, 80–83, 107–111)

Delias aroae angiensis Talbot, 1928: 43; Talbot, 1928–1937: 192, pl. 10, fig. 43 (valva); 1932: 84.

Delias aroa [*sic*] *angiensis* Talbot: Roepke, 1955: 205; D'Abrera, 1990: 134.

Delias angiensis Talbot: Orr & Sibatani, 1985: 14, fig. 27, 28; Yagishita, 1993: 107, pl. 50, figs 1–6, text 117; Tuzov, 1995: 114; Mastrigt, 2003: 63.

Forewing (*male*). Vein CuA_1 length: 8.9–11.0 mm, 9.72 ± 0.55 mm (mean ± SD, n = 30). Black width index: 0.39–0.53, 0.45 ± 0.03 (mean ± SD, n = 30). Wing marking underside (Fig. 21): extent of black marginal band less than 1/2 of the discal cell area. Scent scale length: 290–383 μm, 319± 16.83 μm (mean ± SD, n = 30).

Male genitalia (Fig. 28): Phallus (Figs 41–43): cephalic portion of basal prong in lateral view relatively reduced compared with caudal portion of basal prong (the latter not rounded; *cf. D. a. aroae* and *a. yabensis*); Juxta (Figs 80–83): arrowhead shaped, 0.31–0.38, 0.34 ± 0.03 (mean ± SD, n = 4) times as long as its median width; Uncus (Figs 107–111): outer lobes in dorsal view relatively shorter than the middle lobe.

Material examined (n = 30♂): 12♂, viii, 1996. Hingk, Arfak Mountains.; 18♂, vii, 1996. Arfak Mountains.

***Delias pheres* Jordan** (Figs 5, 6, 13, 14, 22, 23, 29, 44–49, 84–86, 112–119)

Delias aroae pheres Jordan, 1911: 588.

Delias pheres Jordan: Talbot, 1928–1937: 188, pl. 2, fig. 36 (uncus), pl. 10, fig. 42 (valva), pl. 17, fig. 1; 1932: 83; Roepke, 1955: 203; Orr & Sibatani, 1985: 14, 15, figs 6, 13; D'Abrera, 1990: 133; Yagishita, 1993: 109, pl. 51, figs 1, 2, text 119; Tuzov, 1995: 114; Lachlan, 2000: fig. 10; Mastrigt, 2003: 67, pl. 3, figs 7, 8.

Forewing (male). Vein CuA_1 length: [West Papua] 9.2–11.8 mm, 10.52 ± 0.55 mm (mean ± SD, n = 91); [Papua New Guinea] 9.5–11.2 mm, 10.34 ± 0.59 mm (mean ± SD, n = 7). Black width index: [West Papua] 0.51–0.75, 0.62 ± 0.05 (mean ± SD, n = 91); [Papua New Guinea] 0.66–0.75, 0.71 ± 0.03 (mean ± SD, n = 7). Wing marking underside (Figs 22, 23): extent of black marginal band approximately 1/2 of the discal cell area. Scent scale length: 325–388 μm, 356 ± 17.16 μm (mean ± SD, n = 40).

Male genitalia (Fig. 29): Phallus (Figs 44–49): cephalic portion of basal prong well developed, equal in size to caudal portion of basal prong; Juxta (Figs 84–86): arrowhead shaped, gradually widening anteriorly; Uncus (Figs 112–119): outer lobes relatively smaller than the middle lobe, basal part of the middle lobe somewhat wide.

Material examined (99♂): [West Papua]: 5♂, x. 2002. Tembagapura; 2♂, 29. xii. 1990. Ilaga, Jila River; 3♂, 3. ii. 1994. Ilaga, Wuluen River; 1♂, 6. ii. 1991. Tiom, Air Garam II; 1♂, 6. ii. 1995. Tiom–Karbaga, K. Funahashi leg.; 2♂, 7. ii. 1995. Tiom, Tabokakar River, K. Funahashi leg.; 2♂, 8–15. xi. 1991. Makki, Makki River; 2♂, 23–28. xi. 1992. Kanggime, Yawon River; 1♂, 7. iii. 1998. Mbua, Bua River (*ca.* 2,300 m), W. Ones leg.; 3♂, 1–7. V. 1993. Habbema, Habbema River; 2♂, 12. ix. 1995. Welesi, K. Funahashi leg.; 1♂, ix. 19–20. 1992. Pass Valley, Bi River; 9♂, 1. ix. 1993. *ditto*, Seg River, K. Funahashi leg.; 10♂, 5. ix. 1999. Pugima, Huan River (*ca.* 2,420 m), K. Funahashi leg.; 10♂, 29. vii. 1998. Yohosin, Mugi River, K. Funahashi

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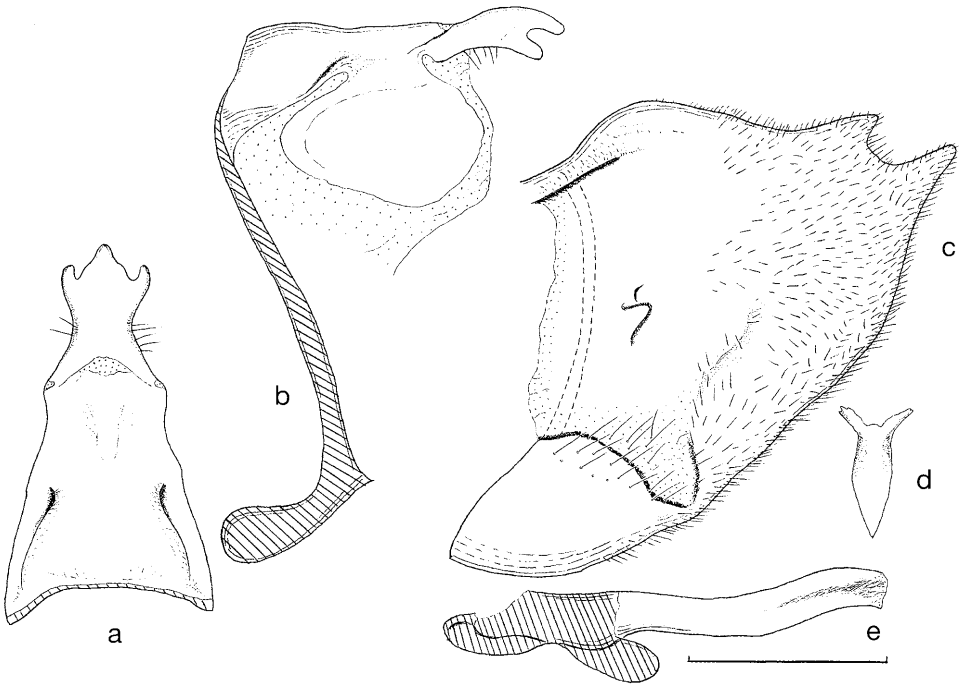

Fig. 29. Male genitalia of *Delias p. pheres* from Aipomek, West Papua. For explanation of a–e, see legend of Fig 27. Scale bar 1 mm.

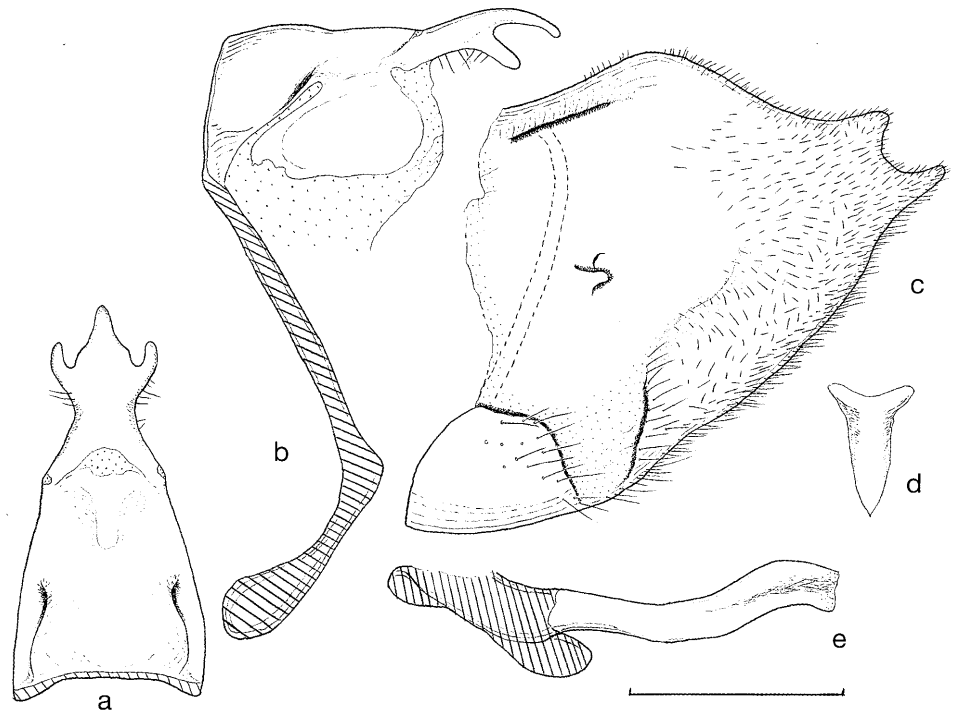

Fig. 30. Male genitalia of *Delias s. subapicalis* from Kerowagi, Papua New Guinea. For explanation of a–e, see explanation to Fig 27. Scale bar 1 mm.

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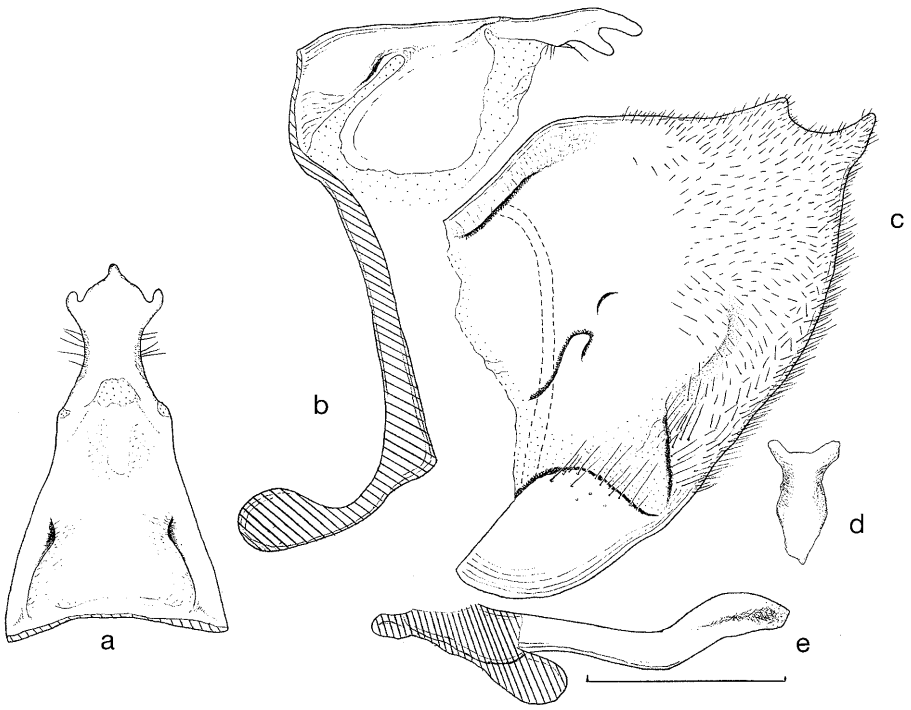

Fig. 31. Male genitalia of *Delias i. inopinata* from Bolobip, Papua New Guinea. For explanation of a–e, see explanation to Fig 27. Scale bar 1 mm.

leg.; 2♂, 16–26. iii. 1993. Langda, Minyo River; 5♂, viii. 28, 1997. Aipomek, Mumye River (*ca.* 2,280 m), K. Funahashi leg.; 10♂, 31. viii. 1997. Aipomek–Debum, Dipsil River (*ca.* 2,150 m), K. Funahashi leg.; 11♂, 2. ix. 1997. Amko–Nalca, Amko River (*ca.* 2,600 m), K. Funahashi leg.; 5♂, 28–29. viii. 1991. Abmisibil, Okkim River; 6♂, 26. ii. 1997. Okibibab, Mong River. [Papua New Guinea]: 2♂, 9. viii, 2000. Bimin (West Sepik Prov.), Atem River (*ca.* 2,100 m), K. Funahashi leg.; 1♂, 12. viii, 2000. *ditto*; 3♂, 11. viii. 2000. Bimin, Woba River (*ca.* 1,960 m), K. Funahashi leg.

Delias pheres approximata **Joicey & Talbot, stat. rev.** (Figs 87, 120, 121)

Delias phaeres [*sic*] *approximata* Joicey & Talbot, 1922: 309, pl. 8 (1924), figs 5–7; 1928–1937: 188,189, pl. 2, fig. 37, pl. 6, fig. 21 (scent scale); 1932: 83, 84; D'Abrera, 1990:133.

Delias approximata Joicey & Talbot: Orr & Sibatani, 1985: 15, 16, figs 3, 14, 15; Yagishita, 1993: 103, pl. 48, figs 3–8, text 114; Tuzov, 1995: 114; Mastrigt, 2003: 63, 64, pl. 4, figs 5, 6.

Forewing (male). Vein CuA_1 length: 9.3–11.5 mm, 10.59 ± 0.55 mm (mean ± SD, n = 17). Black width index: 0.50–0.71, 0.57 ± 0.06 (mean ± SD, n = 17). Wing marking underside: extent of black marginal band approximately 1/2 of the discal cell area. Scent scale length: 325–373 μm, 346 ± 11.68 μm (mean ± SD, n = 40).

Male genitalia: same as those of *D. p. pheres*.

Material examined (17♂): 2♂, vi. 1989. Kamu Valley (1,700 m); 3♂, vii. 1996. Moanamani; 12♂, vi. 1996. Epomani.

Delias subapicalis **Orr & Sibatani** (Figs 7, 15, 24, 30, 50–52, 88, 89, 122, 123)

Delias subapicalis Orr & Sibatani, 1985: 16, 17, fig. 10; Yagishita, 1993: 107, pl. 50, figs 7, 8, text 118; Tuzov, 1995: 114; Parsons, 1999: 307, pl. 10 (dorsum & valva), pl. 34, figs 841–844; Mastrigt, 2003: 68.

Forewing (male). Vein CuA_1 length: 9.9–12.0 mm, 10.43 ± 0.45 mm (mean ± SD, n = 25). Black width index: 0.31–0.50, 0.41 ± 0.03 (mean ± SD, n = 25). Underside wing markings (Fig. 24): extent of black marginal band approximately 2/3 of the discal cell area, its band slightly separate from the discocellular vein with scattered black scales. Scent scale length: 352–375 μm, 365 ± 5.97 μm (mean ± SD, n = 40).

Male genitalia: Phallus (Figs 50–52): cephalic portion of basal prong well developed; Juxta (Figs 88, 89): arrowhead shaped, gradually widening anteriorly; Uncus (Figs 122, 123): outer lobes relatively shorter than the middle lobe; basal part of the middle lobe extending forward.

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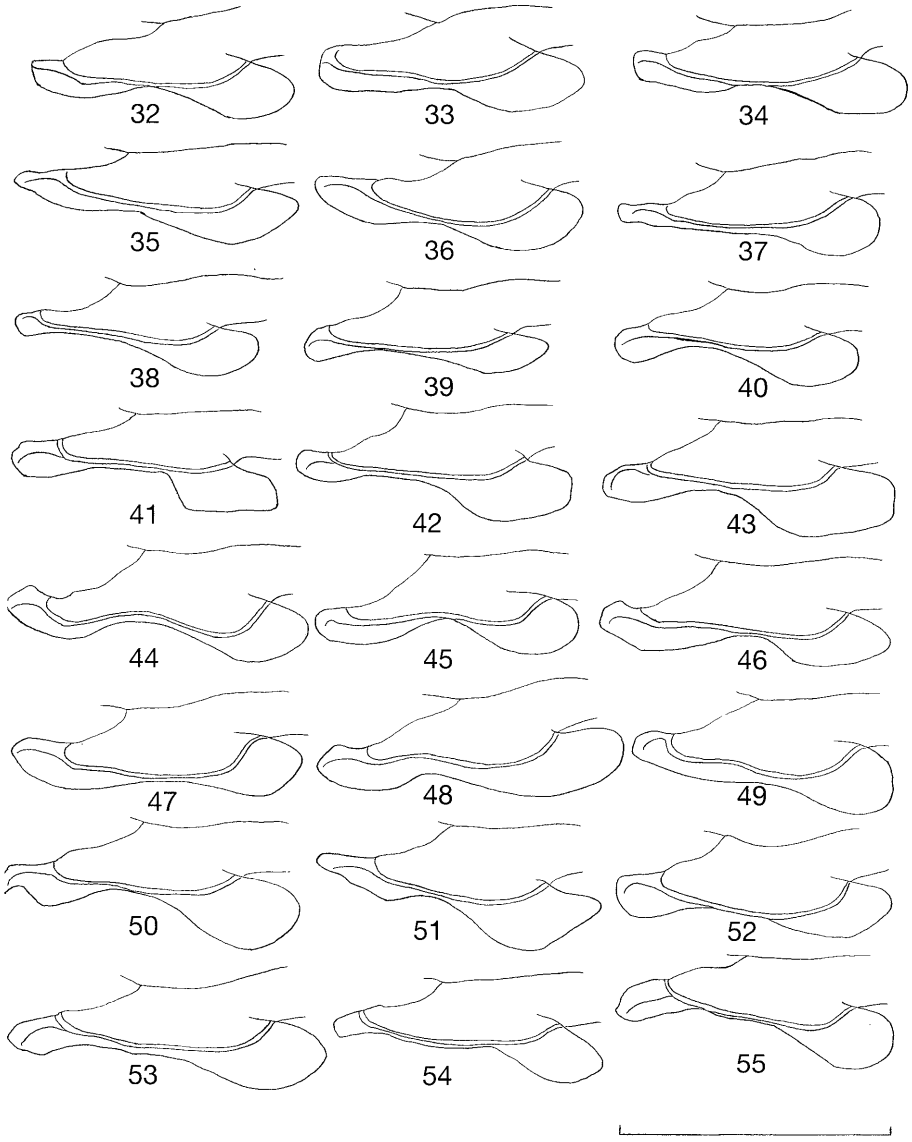

Figs 32–55. Basal prongs of phallus (lateral) of *Delias* spp. 32–37: *D. a. aroae* (32: Okapa. 33, 34: Bimin. 35: Borme. 36: Welesi. 37: Habbema). 38–40: *D. a. yabensis* (38, 39: Mapia. 40: Bomomani). 41–43: *D. angiensis* (Arfak Mountains). 44–49: *D. p. pheres* (44–46: Aipomek. 47: Tiom. 48: Tembagapura. 49: Bimin). 50–52: *D. s. subapicalis* (Kerowagi). 53–55: *D. s. sibatanii* (53: Aipomek. 54, 55: Pass Valley). Scale bar 1 mm.

Material examined (n = 25♂): 12♂, iv. 1995. Kerowagi (Simbu Prov.), 1♂, 8. x. 1995. *ditto*, 9♂, 21. x. 1996. *ditto*, 3♂, 14. ii. 2003. Gembok (Simbu Prov.) .

***Delias subapicalis sibatanii* Mastrigt** (Figs 8, 16, 25, 53–55, 90, 91, 124–126)

Delias subapicalis sibatanii Mastrigt, 2003: 57–60, pl. 2, figs 1–8.

Forewing (male). Vein CuA_1 length: 9.2–11.6 mm, 10.36 ± 0.55 mm (mean ± SD, n = 34). Black width index: 0.33–0.45, 0.41 ± 0.03 (mean ± SD, n = 34). Underside wing markings (Fig. 25): extent of black marginal band approximately 2/3 of the discal cell area, its band slightly separate from the discocellular vein with scattered black scales. Scent scale length: 350–413 μm, 378 ± 15.33 μm (mean ± SD, n = 30).

Male genitalia: Phallus (Figs 53–55): cephalic portion of basal prong well developed; Juxta (Figs 90, 91): arrowhead shaped, gradually widening anteriorly; Uncus (Figs 124–126): outer lobes relatively shorter than the middle lobe; basal of the middle lobe extending forward.

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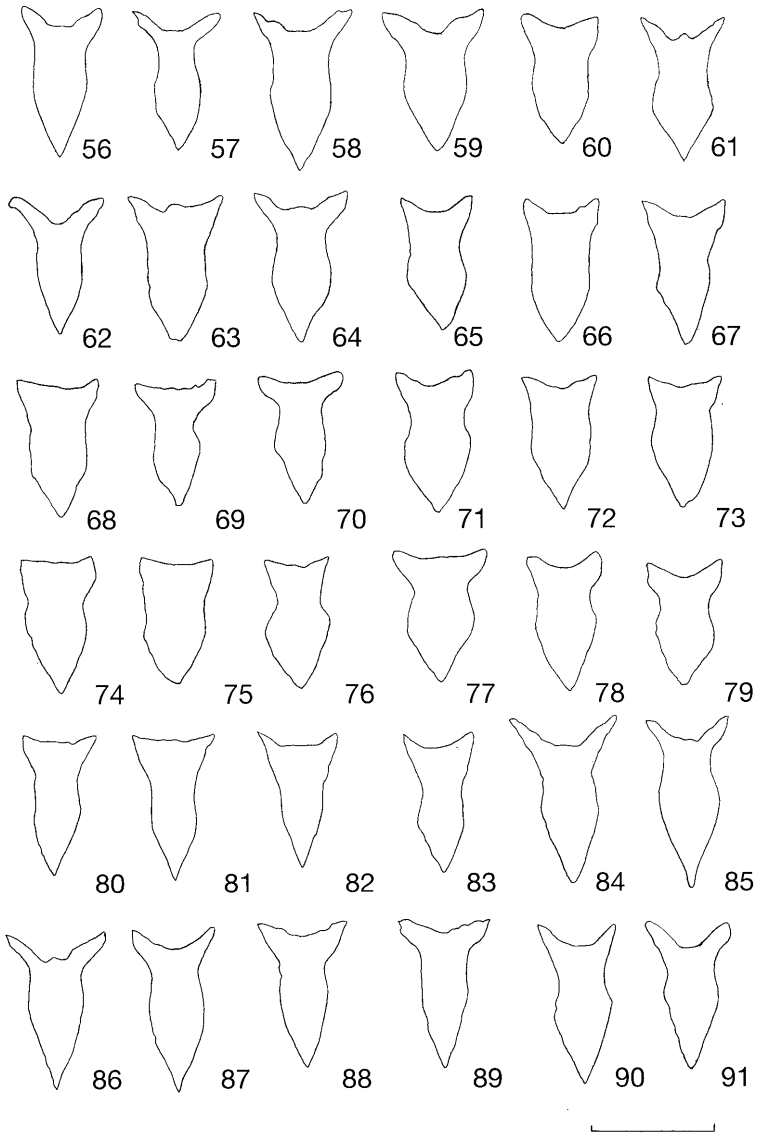

Figs 56–91. Juxta of *Delias* spp. (posterior). 56–67: *D. a. aroae* (56, 57: Okapa. 58: Bimin. 59–61: Borme. 62, 63: Kobakma. 64, 65: Welesi. 66, 67: Pass Valley–Kobakma); 68–79: *D. a. yabensis* (68–73: Mapia. 74: Moanemani. 75: Idedua. 76, 77: Epomani. 78, 79: Bomomani). 80–83: *D. angiensis* (Arfak Mountains). 84–86: *D. p. pheres* (84: Bimin; 85: Aipomek. 86: Pass Valley). 87: *D. p. approximata* (Moanamani). 88, 89: *D. subapicalis* (Kerowagi). 90, 91: *D. s. sibatanii* (90: Aipomek; 91: Pass Valley). Scale bar 0.5 mm.

Material examined (n = 34♂): 11♂, 29. iv, 1994. Pass Valley, Seg River (*ca.* 1,900 m), K. Funahashi leg.; 11♂, 2. ix. 1997. 8♂, 11. ix, 1995. *ditto*, K. Funahashi leg.; Amko–Nalca, Amko River (*ca.* 2,600 m), K. Funahashi leg.; 4♂, 25–27. viii. 1991. Abmisibil, Oktanglap River.

Delias inopinata **Lachlan** (Figs 9, 17, 31)

Delias inopinata Lachlan, 2000: 74, figs 7, 8, 13, 14 (dorsum & valva); Mastrigt, 2003: 66.

Forewing (male). Vein CuA_1 length: 10.8–11.2 mm, 11.0 ± 0.2 mm (mean ± SD, n = 2). Black width index: 0.54–0.55, 0.54 ± 0.003 (mean ± SD, n = 2). Underside wing markings (Fig. 26): black marginal band extends to the entire discal cell area. Scent scale length: 400–418 μm, 408 ± 6.58 μm (mean ± SD, n = 20).

Male genitalia (Fig. 31): Phallus: cephalic portion of basal prong well developed; Juxta: arrowhead shaped, gradually widening anteriorly; Uncus: outer lobes of uncus relatively

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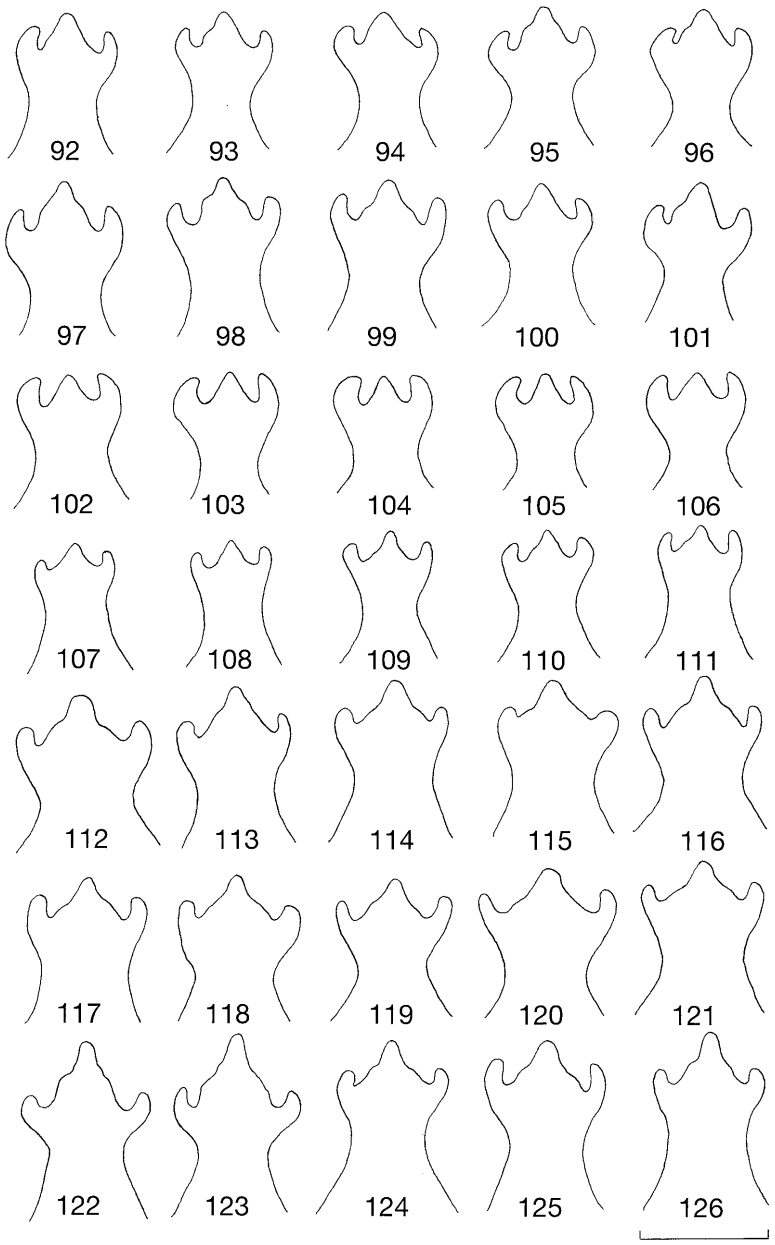

Figs 92–126. Uncus of *Delias* spp. (dorsal). 92–101: *D. a. aroae* (92: Okapa. 93: Bimin. 94: Borme. 95: Pugima; 96: Kobakma. 97: Welesi. 98: Habbema. 99, 100: Pass Valley–Kobakma. 101: Kanggime). 102–106: *D. a. yabensis* (102: Moanemani. 103: Mapia. 104: Epomani. 105: Bomomani. 106: Idedua). 107–111: *D. angiensis* (Arfak Mountains). 112–119: *D. pheres* (112: Bimin. 113, 114: Aipomek. 115, 116: Pass Valley. 117: Welesi. 118: Tiom. 119: Tembagapura). 120, 121: *D. p. approximata* (Moanamani). 122, 123: *D. s. subapicalis* (Kerowagi). 124–126: *D. s. sibatanii* (124, 125: Aipomek. 126: Pass Valley).

shorter than the middle lobe; basal part of the middle lobe somewhat wide.

Material examined (3♂): 18. ix. 2001. Bolobip (Western Prov.), Mt Faium, Bol River (ca. 1,800 m), K. Funahashi leg.

Results

Vein CuA_1 length

The results of the analysis are shown in Table 2. The means of the CuA_1 length significantly differed between *aroae/pheres*, *aroae/subapicalis*, *angiensis/pheres*, and *angiensis/*

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Table 2. Mean ± SD and SE of vein CuA_1 length, scent scale length, and black width index of the four or five species. Differences between means for each species are indicated as significant (s) or non-significant (ns) ($p < 0.01$ by the Tukey–Kramer test for vein CuA_1 length and scent scale length, $p < 0.01$ by the Steel–Dwass test for black width index). ar, *D. aroae*; an, *D. angiensis*; ph, *D. pheres*; su, *D. subapicalis*, in; *D. inopinata*. Subspecies are combined (except *angiensis* and *inopinata*). *not calculated (sample sizes too small in *inopinata*).

Measurement	Species	No. of samples	Mean	SD	SE	Significance								
						ar : *an*	*ar* : *ph*	*ar* : *su*	*ar* : *in*	*an* : *ph*	*an* : *su*	*an* : *in*	*ph* : *su*	*ph* : *in*
Vein CuA_1 length (mm)	*aroae*	126	9.964	0.455	0.041	ns	s	s	*	s	s	*	ns	*
	angiensis	30	9.720	0.564	0.103									
	pheres	115	10.524	0.565	0.055									
	subapicalis	60	10.410	0.524	0.068									
Black width index	*aroae*	126	0.431	0.049	0.004	ns	s	ns	*	s	s	*	s	*
	angiensis	30	0.446	0.038	0.007									
	pheres	115	0.619	0.058	0.005									
	subapicalis	60	0.414	0.030	0.004									
Scent-scale length (μm)	*aroae*	100	325.370	17.238	1.724	ns	s	s	s	s	s	s	s	s
	angiensis	30	318.500	17.118	3.125									
	pheres	80	350.938	15.673	1.752									
	subapicalis	30	371.608	15.589	2.846									
	inopinata	20	408.278	6.584	1.472									

Table 3. Mean ± SD and SE of black width index parameters of *D. aroae* at six localities. Differences between means within each location are indicated as significant (s) or non-significant (ns) (by Tukey–Kramer test). *$p < 0.05$, **$p < 0.01$.

Sites/Region	Number of samples	Mean	SD	SE	Significance				
Weyland Mts	26	0.372	0.031	0.006	Wey/Wel**	Wey/Pas**	Wey/Bor**	Wey/Bim**	Wey/Oka**
Welesi	23	0.435	0.041	0.009	Wel/Pas : ns	Wel/Bor : ns	Wel/Bim**	Wel/Oka*	
Pass Valley	26	0.426	0.031	0.006	Pas/Bor : ns	Pas/Bim**	Pas/Oka**		
Borme	13	0.422	0.032	0.009	Bor/Bim**	Bor/Oka**			
Bimin	23	0.476	0.036	0.008	Bim/Oka : ns				
Okapa	15	0.473	0.024	0.006					

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Table 4. The black width index of *D. aroae* individuals in each of the three regions.

Black width index	Number of samples	Regions					
		Weyland Mts (W. Papua)		Central Mts (W. Papua)		Papua New Guinea	
		n	%	*n*	%	*n*	%
<0.35	6	6	(100)	0		0	
0.4	29	16	(55)	13	(45)	0	
0.45	47	4	(9)	33	(70)	10	(21)
0.5	36	0		16	(44)	20	(56)
0.55	7	0		0		7	(100)
0.55<	1	0		0		1	(100)

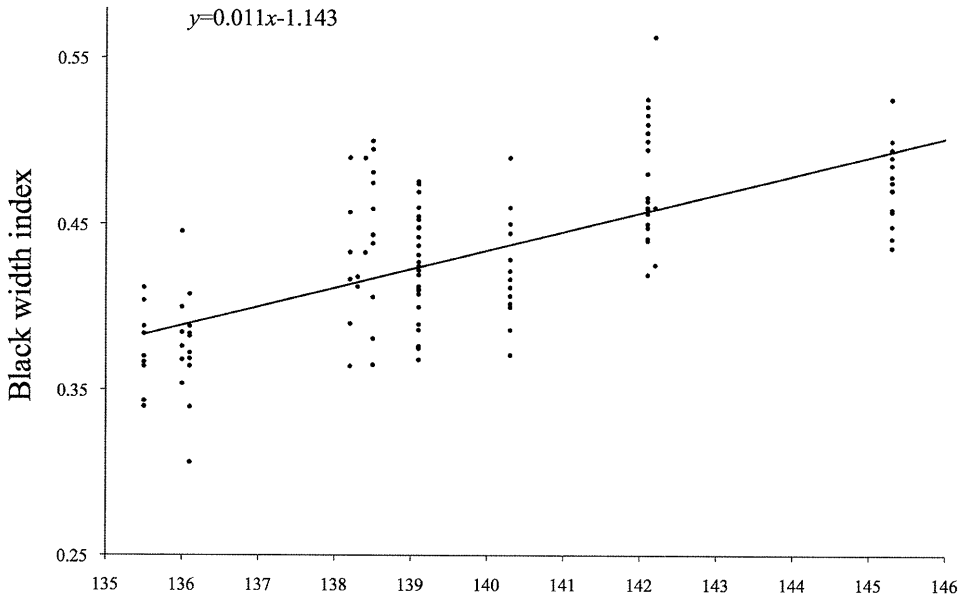

Fig. 127. Scatter plots relating black width index to longitude in *D. aroae*. A single regression line of black width index on longitude is shown.

subapicalis, but not between *aroae/angiensis* and *pheres/subapicalis* (subspecies combined).

In addition, regional units were analyzed within *aroae*, and compared with 126 individuals among three named taxa: *a. aroae* (n = 38), ssp. *yabensis* (n = 26), and ssp. *balimensis* (n = 62); no significant difference was observed between taxa. The same trend was observed in *pheres*; comparisons were made with 115 individuals between two named taxa, *i.e.*, *p. pheres* (n = 91), ssp. *approximata* (n = 17), and unnamed Papua New Guinea units (n = 7), and no significant difference was observed between the taxa or units.

Black width index

The results of the analysis are shown in Table 2. The means of the black width index significantly differed between *aroae/pheres*, *angiensis/pheres*, *angiensis/subapicalis*, and *pheres/subapicalis*, but not between *aroae/angiensis* and *aroae/subapicalis* (combined subspecies). Moreover, the population units were analyzed within *aroae* and *pheres* (see Discussion for details).

Underside wing markings

Based on these results, the wing markings on the underside of the forewing were classified into three groups.

Group 1 (*aroae, balimensis, yabensis, angiensis*): extent of black marginal band less than 1/2 of the discal cell area (Figs 19–21), the band obviously not reaching the discocellular veins; *Group 2* (*pheres, approximata*): extent of black marginal band approximately 1/2 of the discal cell area (Figs 22, 23), the band obviously reaching the discocellular veins; *Group 3* (*subapicalis, inopinata*): extent of black marginal band more than 2/3 of the discal cell area (Figs 24–26).

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Scent scale length

The results of the analysis are shown in Table 2. The means of scent scale length significantly differed between *aroae/pheres*, *aroae/subapicalis*, *aroae/inopinata*, *angiensis/pheres*, *angiensis/subapicalis*, *angiensis/inopinata*, *pheres/subapicalis*, *pheres/inopinata* and *subapicalis/inopinata* (combined subspecies, except *angiensis* and *inopinata*), but not between *aroae/angiensis*.

Male genitalia

Based on these results, male genital characteristics were categorized into three groups.

Group 1 (small-sized groups: a*roae, balimensis, yabensis, angiensis*) (Figs 27, 28). Phallus (Figs 32–43): cephalic portion of basal prong in lateral view relatively reduced compared with caudal portion in all members (caudal portion of basal prong not rounded in *angiensis*, Figs 41–43). Juxta (Figs 56–83): arrowhead shaped, somewhat wider in *yabensis* (Figs 68–79) than in other members (*yabensis*, 0.50 ± 0.05; *aroae*, 0.44 ± 0.04; *angiensis*, 0.34 ± 0.03 times as long as median width). Uncus (Figs 92–111): outer lobes well developed, equal in length to the middle lobe in *yabensis* (Figs 102–106). *Group 2* (large-sized group 1: *pheres, approximata*) (Fig. 29). Phallus (Figs 44–49): cephalic portion of basal prong well developed, equal in size to the caudal portion of basal prong. Juxta (Figs 84–87): arrowhead shaped, gradually widened anteriorly. Uncus (Figs 112–121): outer lobes relatively smaller than the middle lobe; basal part of the middle lobe somewhat wide. *Group 3* (large-sized group 2: *subapicalis, inopinata*) (Figs 30, 31). Phallus (Figs 50–55): cephalic portion of basal prong reduced; caudal portion of basal prong extremely well developed laterally. Juxta (Figs 88–91): arrowhead shaped, gradually widening anteriorly. Uncus (Figs 122–126): basal part of the middle lobe extending forward (particularly in *s. subapicalis*).

Discussion

For comparing the black width index in *D. aroae*, mean values for the six local populations are given in Table 3. The Weyland populations from the western part of New Guinea have narrower black apical band than other populations. The Papua New Guinean populations from the eastern part of New Guinea have a broader black apical band than other populations. Therefore, the width of the black apical band gradually narrows in the western populations, whereas it gradually broadens in the eastern populations. Consequently, the extent of the black apical band differs between three regional populations, *i. e.*, Weyland, Central and Papuan populations and is an aspect of the east–west cline (Table 4). Simple regression analysis revealed a correlation between black width index and longitude ($r = 0.665$, $p < 0.01$) in *D. aroae* (Fig. 127).

Delias aroae balimensis (current status: *D. balimensis*) was described from the Baliem Valley in central West Papua. The taxon clearly overlaps with the typical *aroae* in following morphological characteristics: vein CuA_1 length, scent scale length and male genital characteristics, and reflected that the status of *D. balimensis* as merely a cline form of *D. a. aroae* (**syn. nov.**).

Delias aroae yabensis (current status: *D. yabensis*) was described from the Weyland Mountains in western West Papua. The taxon clearly overlaps with the typical *aroae* in following morphological characteristics: vein CuA_1 length, scent scale length and male genital characteristics. However, in most specimens the male genitalia are somewhat different in shape (uncus and juxta). Therefore, its status as a subspecies of *D. aroae* has been revised (**stat. rev.**).

Delias angiensis (originally *D. aroae angiensis*) is distributed in the Arfak Mountains, and is isolated from other members of the species complex. Talbot (1928) indicated in the original description that "Not very different from the typical British New Guinea subspecies (= typical *aroae* of Papua New Guinea), with which it agrees on the upperside." Moreover in my results, the taxon is strongly related to the typical aroae in following morphological characteristics: vein CuA_1 length, black width index, scent scale length and male genital characteristics. However, the caudal portion of the basal prong in the lateral view of the phallus was relatively angled (the prong was more rounded in *aroae*). This morphological difference has been recognized as a specific rank in this study.

Delias pheres is widely distributed in montane New Guinea and is sympatric with *D. aroae* in many habitats. The two species are occasionally confused as regards subspecific rank, but they are distinctly different in vein CuA_1 length, black width index and scent scale length. Moreover in *pheres*, the cephalic portion of the basal prong of the phallus in the male genitalia is more developed than in *D. aroae* (including ssp. *yabensis*).

Delias p. approximata (current status: *D. approximata*) was described by Joicey and Talbot (1922) from the Weyland Mountains in West Papua. They noted "Upperside of fore wing with the black entering the end of the cell but slightly, and mostly bordered by the discocellulars. The white patch in 3 mostly larger than in the type form." In addition, Talbot (1928) commented in his monograph that "This race is distinguished by the extended white in the cell of the fore wing below but is otherwise very like the typical form." This subspecific difference would be

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insignificant, because the extent of the black apical band is representative of the east–west cline. Simple regression analysis revealed a correlation between black width on the upperside of the forewing and longitude ($r = 0.524$, $p < 0.01$; regression line, $y = 0.017x - 1.766$). The taxon clearly overlaps with the typical *pheres* in following morphological characteristics: vein CuA_1 length, scent scale length and male genital characteristics, and reflected that the status of *D. p. approximata* as merely a cline form of typical *pheres*. In contrast, Talbot (1928) illustrated the differences in male genitalia (uncus) between typical *pheres* and *p. approximata*. In my investigations, no distinct differences were observed between the genitals of two taxa. I defer the synonymity between them. Therefore, the status of *approximata* is revived as a subspecies of *D. pheres* (**stat. rev.**).

Delias subapicalis (including ssp. *sibatanii*) has a uniformly black marginal band covering approximately 2/3 of the discal cell area on the underside of the forewing. The vein CuA_1 length of the forewing is not significantly different from that in *D. pheres*, and the black width index is not significantly different from that in *D. aroae*. However, scent scale length in *subapicalis* is significantly greater than that in *aroae* and *pheres*. The male genitalia of the typical *subapicalis* and *s. sibatanii* taxa were separately analyzed; the median lobe of the uncus is well developed in subapicalis compared with that *D. s. sibatanii*.

Delias inopinata has expansive black scales on the discal cell area on the underside of the forewing. This species is superficially similar to *D. subapicalis*, but differs in length of scent scale (*subapicalis*: 365 ± 5.97 μm (mean ± SD, $n = 40$); *s. sibatanii*: 378 ± 15.33 μm (mean ± SD, $n = 30$); *inopinata*: 408 ± 6.58 μm (mean ± SD, $n = 20$).

In conclusion, the *Delias aroae* species complex comprises the following species/subspecies on the results of the present review: *D. a. aroae, D. a. yabensis, D. angiensis, D. p. pheres, D. p. approximata, D. s. subapicalis, D. s. sibatanii, D. i. inopinata* and *D. i. orri*.

Key to species and subspecies of the *aroae* species complex *s. str.* based on the males

1 Forewing upperside; black width index on the vein $CuA_1 < 0.55$ ..... (Mainland New Guinea/Weyland Mountains) *p. pheres/p. approximata*
– Forewing upperside; black width index on the vein $CuA_1 > 0.55$ 2
2 Forewing underside; extent of the black marginal band less than 1/2 of the discal cell area 3
– Forewing underside; extent of the black marginal band more than 1/2 of the discal cell area 5
3 Hindwing underside; white median band reaching dorsum. Phallus: caudal portion of basal prong rounded in lateral aspect 4
– Hindwing underside; white median band not reaching dorsum. Phallus: caudal portion of basal prong somewhat angled in lateral aspect ..... (Arfak Mountains) *angiensis*
4 Uncus: outer lobes of uncus well developed, which is as long as the median lobe in length ..... (Weyland Mountains) *aroae yabensis*
– Uncus: outer lobes of uncus relatively shorter than that of the middle lobe in length ..... (Mainland New Guinea, except Arfak and Weyland Mountains) *a. aroae*
5 Forewing underside; extent of the black marginal band more than 2/3 of the discal cell area ..... *i. inopinata*
– Forewing underside; extent of the black marginal band approximately 2/3 of the discal cell area 6
6 Upperside forewing; black marginal band with 3 or 4 small white spots. Uncus: basal part of the middle lobe extending forward ..... (Papua New Guinea) *s. subapicalis*
– Upperside forewing; black marginal band without small white spot. Uncus: basal part of the middle lobe extending forward slightly .....(West Papua) *s. sibatanii*

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摘　要

ニューギニア島産*Delias aroae*種群（鱗翅目，シロチョウ科）に関する分類学的再検討（船橋勝幸）

島嶼部を除くニューギニア本島の山地から高地帯にかけて広く生息する狭義の*aroae*種群は，互いに極めてよく似た外観をもち，さらに同一種内での個体変異の幅が広いことから種間関係が不明瞭な一群である．

今般，島内各地から近年得られた標本により種群内の分類学的再検討を行った．亜種を含めた（入手できなかった*D. inopinata orri*を除く）各種間の検討は♂の5形質，前翅裏面中室内黒色帯の発達程度，前翅CuA_1脈長，前翅黒帯指数（black width index; 表面外縁黒帯幅/ CuA_1脈長），前翅発香鱗長及び交尾器形態に基づいて行い，またこれらの形態を記載した．

その結果，本種群は*aroae, angiensis, pheres, subapicalis, inopinata*の5種に分割されるとともに，その中の広域分布種である2種，*D. aroae*及び*D. pheres*の前翅表外縁黒帯幅については経度との関係が示唆された．

これらの検討結果に基づいて，*D. balimensis*を*D. a. aroae*のシノニムとして取り扱い，また西パプア西部のWeyland山脈を基産地とする*D. yabensis*を*D. aroae*の亜種として，同じく*D. approximata*を*D. pheres*の亜種としてそれぞれ降格した．

以上のことから現在本種群は，*D. a. aroae, D. a. yabensis, D. angiensis, D. p. pheres, D. p. approximata, D. s. subapicalis, D. s. sibatanii, D. i. inopinata, D. i. orri*の9タクソンで構成されることとなる．

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